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Movements, Survival, and Sightability of White-Tailed Deer in Southeastern South Dakota

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MOVEMENTS, SURVIVAL, AND SIGHTABILITY OF WHITE-TAILED DEER IN SOUTHEASTERN SOUTH DAKOTA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

MOVEMENTS, SURVIVAL, AND SIGHTABILITY OF WHITE-TAILED DEER IN SOUTHEASTERN SOUTH DAKOTA

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To effectively manage white-tailed deer (*Odocoileus virginianus*) populations, managers need to identify population parameters including but not limited to movements, survival and cause-specific mortality. It also is helpful to examine population size and density. The primary objectives of my study were to document seasonal migration, estimate survival rates for female adult white-tailed deer, and generate a sightability model for deer in southeastern South Dakota. Secondary objectives were to calculate seasonal home ranges and document cause-specific mortality. Forty four adult female white-tailed deer were monitored from February 2009 to January 2011 in Bon Homme and Yankton counties. I documented 38 seasonal movements during four migration periods; spring 2009 (n = 9), fall 2009 (n = 5), spring 2010 (n = 13), and fall 2010 (n = 11). Mean migration distance was 10.6 km (SE = 1.1). I calculated 82 seasonal home ranges during three seasons; summer 2009 (n = 21), winter 2009-2010 (n = 30), and summer 2010 (n = 31). Mean 95% summer and winter home range size was 2.0 km^2 (SE = 0.2, n = 52) and 2.3 km^2 (SE = 0.3, n = 30), respectively. During this study, 19 deer died and the overall (24 month) survival rate was 0.47 (SE = 0.08, n =33). Annual survival rates for 2009 and 2010 were 0.62 (SE = 0.09, n = 24) and 0.74 (SE = 0.07, n = 33) respectively. Survival was predominantly dependent upon human-related factors. Natural causes (5%) were minimal when compared to human-related causes (84%). Hunting, including wounding loss, was responsible for 37% of all mortalities. Two sightability flights were conducted in 2009 and four additional flights were conducted in 2010. Variables examined were group size and movement, effect of sunlight or shade, % canopy, % snow cover, and habitat the variables trees, tall grass, short grass, standing corn, agricultural fields, and cattails. Canopy cover prevented visual observation of deer because most of the canopy consisted of mature eastern red cedar (*Juniperous virginiana*). These data can be used to improve population models in this region of South Dakota; however, further monitoring of these variables and others are critical to developing a well-defined population model for white-tailed deer in the region.

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CHAPTER 1

INTRODUCTION AND STUDY SITE DESCRIPTION

Introduction

Over the course of the last century, white-tailed deer (*Odocoileus virginianus*) have recovered from low population levels with prohibited hunting to current levels where deer are considered a nuisance in some areas. When provided with ideal habitat conditions and given the opportunity to expand, white-tailed deer have shown that they are one of the most prolific ungulates in North America. Current agricultural practices in the northern Great Plains provide white-tailed deer with highly nutritious food sources year round as well as available cover during most of the growing season (Cook 1945, Kernohan et al. 2002). This, coupled with limited hunting opportunities in growing urban areas, has allowed white-tailed deer to expand beyond socially acceptable carrying capacities in many areas of their range. Because of this, resource managers must maintain population levels within socially acceptable limits. Too few deer and hunters and animal watchers protest, too many and damage complaints rise, creating additional management issues. To effectively manage populations of white-tailed deer, managers must be aware not only of how many deer are in the population, but what factors, both natural and human-induced, play a role in population ecology.

In eastern South Dakota, white-tailed deer populations are managed according to political boundaries described by county lines. These county lines generally do not follow geographic or physiographic features; thus, populations within given units may fluctuate seasonally as deer migrate between patches of suitable habitat. Because little empirical data exists on white-tailed deer movement in southeastern South Dakota, managers must make assumptions to account for seasonal deer movement or assume that emigration and immigration are equal. This can potentially cause over or under harvest in some units. Recent studies have shown that seasonal deer movement in South Dakota may exceed 10 km (Sparrowe and Springer 1970, Kernohan 1994, Burris 2005, Grovenburg et al. 2009). These movements are typically triggered by climactic factors such as snow depth and minimum temperature (Nelson 1998, Sabine et al. 2002, Brinkman et al. 2005, Grovenburg et al. 2009). Because of climate variability, these conditions can influence deer movement over a temporal window that varies on an annual basis. Variable seasonal movements have the potential to occur before or during annual harvest seasons, greatly affecting the potential for population reduction due to animal exchange across management unit boundaries (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). Thus, knowledge of movement data is critical for effective population management of white-tailed deer in the northern portion of the white-tailed deer distribution.

White-tailed deer in the northern Great Plains may disperse distances in excess of 200 km (Kernohan 1994, Brinkman et al. 2005). Long-distance movements such as these are important in terms of genetic viability and potential disease transfer but can make management difficult because humans have no control over seasonal movements (Oyer et al. 2007, Rosenberry et al. 1999). In addition to movement, mortality is another aspect of population management that must be understood. Documented mortality in the region has shown humans to be the proximate cause of mortality either through hunting or vehicle collisions (Brinkman 2003, Burris 2005, Grovenburg et al. 2011*b*). Because human factors tend to be the leading cause of mortality, current survival estimates are based on hunter harvest surveys and vehicle collision reports. Without specific knowledge for survival rates of a population, over or under harvest is possible, which may result in a population that does not conform to societal norms. Primary objectives of this study were to document seasonal movements and survival rates of adult female white-tailed deer in southeastern South Dakota as well as create an aerial sightability model used for population estimation. Secondary objectives were to document cause-specific mortality and estimate seasonal, annual and overall survival rates, as well as calculate seasonal home range size and document movement strategies in relation to management unit boundaries.

Study Area

The study was conducted from February 2009 to January 2011 in Bon Homme and Yankton counties in southeastern South Dakota. The study site lies predominantly within the James River Lowlands but its eastern border was the James River Highlands (Omernik and Gallant, 1988). Topography was flat to gently rolling with elevations ranging from 368 m above mean sea level in the southeastern part to 579 m above mean sea level in the northwestern region of the area (Ward 1981). Soils of the Lowlands are composed of glacial till with a flat to slightly rolling topography and pocketed with seasonal wetlands (Bryce et al. 1998). The James River Highlands are a collection of three ridges consisting of bedrock with overlying glacial drift. The ridges comprise the northern bluffs of the Missouri River for nearly 32 km surrounding the town of Yankton, South Dakota (Malo 1997).

The western portion of the study area contained vegetation typical of that of a Northern Mixed Grass Prairie while the eastern portion of the study site was dominated by Tallgrass Prairie (Johnson and Larson 1999). While little native prairie exists within the study site, several prairie restorations contained species such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Surrounding wetlands, moist soil species such as reed canarygrass (*Phalaris arundinacea*), common reed (*Phragmites australis*), and cattails (*Typha* spp.) were common (Johnson and Larson 1999). The extreme southern border of the study area was the Missouri River, which was characterized by several wooded draws that were too steep for row-crop agriculture. While deer utilized cattail patches and small woodlots throughout the study area during summer months, these wooded draws provided critical habitat during the winter months. Lower elevations of these draws were dominated by deciduous species such as green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), boxelder (*Acer negundo*), hackberry (*Celtis occidentalis*), and eastern cottonwood (*Populus deltoides*). Much of the higher elevations were dominated by eastern red cedar (*Juniperus virginiana*; Peterson 1984). Some juniper stands were cleared by fire and mechanical methods to increase grazing potential for beef cattle.

Bon Homme county has a moderate climate with warm summers and cool winters. Minimum mean temperatures in January were −13.4° C in January, mean maximum temperatures were 31.3° C in July. The study area typically receives 61.4 cm of precipitation annually with the majority of the rainfall occurring during the growing season (i.e., April through September). Snowfall averages 76.2 cm annually but due to high winds, moderate to severe drifting occurs leaving much of the ground bare during winter (High Plains Regional Climate Center 2010).

In 2009, Bon Homme county had a human population of 6,995. This, coupled with its relatively small land area of 1,459 km^2, placed it 14^{th} of South Dakota's counties in terms of density (4.8 people per km^2; U.S. Census Bureau 2011). There were 563 farms in Bon Homme County in 2007 operating on 124,879 ha (National Agricultural Statistics Service 2010). Major land use in Bon Homme County was agriculture. Nearly 89% of the county was converted to row crop agriculture or was used for hay and pasture land (National Agricultural Statistics Service 2010). In 2009, the two major crops grown in the county were corn and soybeans. Corn was planted on 39,578 ha (27.1%) and beans were planted on 34,155 ha (23.4%). Other major crops in the county were winter wheat and alfalfa.

Yankton county has a moderate climate with warm summers and cool winters. Mean minimum temperatures in January were −14.0° C and mean maximum temperatures in July were 30.2° C. Yankton county receives mean annual precipitation of 61.4 cm with the majority coming during the growing season (i.e. April through September). Mean snowfall totals are 58.2 cm; however, due to high winds mean snow depths rarely exceed 5 cm (High Plains Regional Climate Center).

The human population of Yankton county was 22,438 in 2010. Yankton county has a land area of 1349.8 km^2 placing it fourth of South Dakota's counties in terms of density (16.6 people per km^2; U.S. Census Bureau 2011). There were 658 farms in Yankton county in 2007, operating on 130,406.7 ha (National Agriculture Statistics

Service). Major land use in Yankton county is agriculture. Nearly 96.6% of the county is converted to row crop agriculture or is used for hay and pasture land (National Agriculture Statistics Service 2011). In 2009 the two major crops were corn and soybeans grown on 38,688 ha (29%) and 30,270 ha (22%) respectively. Other major crops were winter wheat and alfalfa.

During this study, the East River Firearms Deer Season dates were 21 November-6 December 2009 and 20 November-5 December 2010 with and additional antlerless season of 26 December-3 January 2009 and 1-9 January 2010. The youth hunting season was 12 September-31 January 2009 and 11 September -31 January 2010. Statewide muzzleloader seasons during fall 2009 and 2010 were 12 December-31 January and 11 December-31 January, respectively, with the 1-31 January dates restricted to antlerless only harvest. Archery season began on 26 September 2009 and 25 September 2010 and convened 31 January both years with 1-31 January restricted to antlerless only harvest. (South Dakota Department of Game, Fish and Parks 2009, 2010).

CHAPTER 2

MOVEMENTS OF ADULT FEMALE WHITE-TAILED DEER IN SOUTHEASTERN SOUTH DAKOTA

Introduction

Throughout the northern portion of their range, white-tailed deer have been shown repeatedly to exhibit a seasonal migration strategy (Marchinton and Hirth 1984, Demarais et al. 2000, Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). These seasonal movements are typically grouped into three subcategories: short-distance, migratory, and dispersal (Kernohan 1994, Kernohan et al. 2002). Short-distance movements are those that result in seasonal home range overlap but likely occur due to resource availability and are typical of moderate climates (Michael 1965, Kammermeyer and Marchinton 1976). Migratory movements are made by deer traveling between seasonal home ranges. These movements can be quite large and are triggered by changing environmental factors during spring and fall (Nelson 1998, Fieberg et al. 2008, Grovenburg et al. 2009). Dispersal movements occur when a deer moves to a new range and no longer exhibits fidelity to the previous home range (Nelson and Mech 1992, McCoy et al. 2005). These movements are permanent and have been documented to exceed 200 km in this region (Kernohan 1994, Brinkman 2003). Due to erratic but potentially severe winter weather, white-tailed deer in eastern South Dakota have been shown to exhibit all three movement patterns (Sparrowe and Springer 1970, Kernohan et al. 2002, Burris 2005, Grovenburg et al. 2009, 2011*a*).

White-tailed deer have been shown to exhibit three migration strategies; non-migratory or resident, obligate, and conditional (Nelson 1995, Van Deelen et al. 1998, Sabine et al. 2002). Obligate migrants are those that migrate each season regardless of conditions. Conditional migrators are those that migrate in some but not all seasons; this phenomenon typically occurs during mild winters when snow depth and temperature are not severe enough to trigger migrations (Hoskinson and Mech 1976, Sabine et al. 2002, Fieberg et al. 2008). Many variables have been examined in an attempt to explain the onset of migration. Cues such as photoperiod, vegetation changes, cloud cover and heredity (Hoskinson and Mech 1976, Nicholson et al. 1997, Nelson 1998) have been suggested to initiate migration; however, snow depth and temperature fluctuations have received the most merit (Verme 1968, Nelson 1998, DelGiudice et al. 2002, Grovenburg et al. 2009).

Migration between summer and winter ranges typically occurs in November and December in northern regions (Sparrowe and Springer 1970, Brinkman 2003, Burris 2005, Grovenburg 2007). As snow depth increases and temperatures drop, deer seek winter areas that provide thermal cover to maximize energy retention (Demarais et al. 2000, Humpal et al. 2001). While on their winter range, deer create a network of highly packed trails through the snow, which reduces the energy required to move from bedding to feeding areas (Parker et al. 1994). Trails also reduce the likelihood of predation (Nelson 1998, Demarais et al. 2000). Spring migration generally occurs during March and April in response to warmer weather and reduced snow cover (Rongstad and Tester 1969, Nelson and Mech 1986*b*, Sabine et al. 2002).

Reasons for the initiation of dispersals have been hypothesized to include social pressures and structure, resource limitation, age, and hunting pressure (Hawkins et al. 1971, Nelson and Mech 1992, Jones et al. 1997, Shaw et al. 2006). Dispersal rates of populations are important to managers because of the potential for disease transmission, genetic transfer, sex ratios, and other critical population parameters (Oyer et al. 2007, Rosenberry et al. 1999). However, because dispersals represent movement into and out of a population, they are difficult and costly to document and thus, are typically assumed to be equal (Johnson 1994).

White-tailed deer movements in eastern South Dakota have been well documented with migration distances typically exceeding 10 km (Sparrowe and Springer 1970, Kernohan 1994, Kernohan et al. 2002, Burris 2005, Grovenburg et al. 2009). Brinkman et al. (2005) also reported migration distances exceeding 10 km in southwestern Minnesota, a highly modified agricultural environment much like eastern South Dakota. While the location for this study contained a mostly agricultural landscape, the Missouri River forms the southern border of the study area. Because the river is contained within an impoundment and forms Lake Lewis and Clark, which in places, is 4.5 km wide, I hypothesized that it was a barrier to movement. Thus, deer would be forced to move in a northerly direction, which likely would result in long migration distances. The objectives of this study were to (1) evaluate seasonal movements of white-tailed deer relative to traditional winter ranges in southeastern South Dakota and (2) calculate seasonal home ranges for deer in this region of South Dakota.

Methods

Female white-tailed deer were captured at two sites (Figure 1) using a helicopter with a shoulder-fired net gun (Jacques et al. 2009, Helicopter Capture Service; Quicksilver Air, Fairbanks, AK, USA). Upon capture, an aircrew member would exit the aircraft and hobble and blindfold deer. Deer were then placed in a load bag and slung below the helicopter to a processing site. Once at the processing site, rectal temperature was monitored continuously until the deer was released. When conditions warranted (rectal temperatures at or above 40° C), a solution of ice water and isopropyl alcohol was immediately applied ventrally in an effort to limit the maximum body temperature of the deer.

Deer were aged as yearling (1.5 yrs) or adult (>1.5 yrs.) using tooth replacement and wear (Severinghaus 1949). Chest and neck girth measurements were used to estimate weight (Weckerly et al. 1987) and a colored, numbered eartag was affixed to one ear while a small, numbered, metal tag was attached to the other ear. An intramuscular injection of a broad-spectrum antibiotic was administered to each deer and they were fitted with radiocollars (Advanced Telemetry System, Isanti, MN, USA) equipped with a mortality sensor designed to increase pulse frequency from 60 beats per minute (bpm) to 120 bpm if collars remained motionless for >8 hours. After processing, the hobbles and blindfold were removed and the deer was released. Total handling time was monitored from the time the deer reached the processing site until the time the deer exited the processing area. All methods pertaining to capture of deer were approved by the Institutional Animal Care and Use Committee (IACUC, Approval No. 08-A028) at South Dakota State University and followed guidelines approved by the American Society of Mammalogists (Sikes et al. 2011).

Radiocollared deer were located a minimum of 2 times per week using a collapsible truck-mounted null-peak antenna system (Brinkman et al. 2002) fixed with an electronic compass (C100 Compass Engine, KVH Industries, Inc., Middletown, RI, USA;

Cox et al. 2002) or a hand-held antenna (Advanced Telemetry Systems, Inc., Isanti, MN, USA). In an attempt to generate winter home ranges following capture, deer were located on successive days while maintaining >20 hours between locations to ensure independence of locations (Kernohan et al. 1996). A minimum of three directional bearings were taken for each deer from pre-determined stations. Azimuths were then entered into the LOCATE III computer program (Nams 2006) to estimate locations. Locations were discarded if the 95% error ellipse was ≥20 hectares (Guiliano et al. 1999). The fixed kernel method was used to calculate home ranges using the home range tools extension in ARCView 3 (Rodgers and Carr 1998). Least squares cross-validation was used to estimate the smoothing parameter (Seaman et al. 1999).

A deer was determined to be a migratory deer if there was no overlap between the respective summer and winter ranges. Total migration distance was calculated using the straight line distance between the harmonic means of winter and summer home ranges (Brinkman 2003, Grovenburg et al. 2009). A migration between summer and winter ranges was defined as fall migration, and migration from winter to summer ranges was defined as spring migration. Date of migration was calculated as the median date between the last and first observations that crossed spring and winter or winter and spring ranges. Migrators who were monitored for ≥2 migratory periods were classified as obligate, conditional, or resident (Brinkman et al. 2005, Grovenburg et al. 2011*a*). Deer were considered obligate migrators if they made one movement to a seasonal range and migrated during every season (Sabine et al. 2002, Brinkman et al. 2005, Grovenburg et al. 2011*a*). Also, deer that migrated every year were considered obligate migrators.

Conditional migrators were those deer that did not migrate during every migration period or made several movements to a seasonal range during a migration period. (Nelson 1995). Resident deer were those that had home ranges that overlapped.

Annual deer winter severity index was calculated for the study area using methods described by DelGiudice et al. (2002). One point was assigned each day that the mean temperature was $\leq -7°C$ and an additional point for each day the snow depth was ≥ 35.0 cm during the months of October-April (National Climatic Data Center 2010, South Dakota Office of Climatology 2011). Based on this system any given day could be assigned a value of 0, 1, or 2.

SAS version 9.1 (SAS Institute 2000) and Oriana version 3.21 (Oriana 2010) were used to conduct statistical analyses. Analysis of Variance (ANOVA) and pairwise comparisons were used to compare home range sizes and migration distances by year, season, and capture site. Circular distributions were used to determine mean migration direction.

Results

A total of 44 adult white-tailed deer was captured and radiocollared using a helicopter and net gun during 2009 (n = 25; Appendix A) and 2010 (n = 19; Appendix B) at two sites in southeastern South Dakota. A total of 31 deer was collared at site 1 and 13 deer were collared at site 2. Deer were monitored from February 2009 through January 2011.

Mean processing time was 2.25 minutes for all captures and ranged from 1.25 to 7.5 minutes (Table 2, 3). Due to an increasing daytime temperature in 2009, chest measurements were not collected on three deer to shorten processing time and prevent overheating. Mean chest girth measurement of measured deer was 102.8 cm (SE = 0.79) and ranged from 89 to 117 cm (Table 2,3). Using the formula derived by Weckerly et al. (1987; $\hat{Y} = -15.97 + 0.08X$), average estimated weight of measured adult does was 66.3 kg (SE = 0.63) and ranged from 55.2to 77.6 kg.

A total of 4,505 locations was collected with a mean 95% error ellipse of 4.7 ha. I documented 38 seasonal movements (Appendix F) during four migration periods; spring 2009 (n = 9), fall 2009 (n = 5), spring 2010 (n = 13), and fall 2010 (n = 11). A total of 82 seasonal home ranges was calculated (Appendicies C, D) during three seasons; summer 2009 (n = 21), winter 2009-2010 (n = 30), and summer 2010 (n = 31).

Spring 2009

During spring 2009, a total of 9 deer (37.5%) migrated a mean distance of 13.2 km (SE = 3.3, Range = 34.1 km; Appendix F). Fifteen deer (62.5%) either did not migrate or died prior to exhibiting migratory behavior during the migration season. Mean migration date was 4 April and ranged from 15 March to 28 April

Two deer exhibited dispersal behavior and dispersed a mean distance of 25.7 km (SE = 0.2, range = 0.3 km). Both of these deer dispersed from capture site 1 on 15 March and remained together until Deer 150935 was harvested on 31 January 2010. The other dispersing individual, Deer 150975, died on 16 February 2010 due to injuries received from a vehicle collision.

Fall 2009

During fall 2009, 5 individuals (23.8%) migrated a mean distance of 10.2 km (SE = 2.3, Range = 6.3; Appendix F). Mean migration date for fall 2009 was 23 November and ranged from 11 October to 8 December. All deer that migrated during spring 2009 and were alive and available to migrate during fall 2009 returned to their winter range.

Deer 150206 moved a distance of 36.9 km during the spring migration period. She was located for the last time on her summer range on 15 November 2009. On 21 November, deer 150206 was harvested approximately 21 km southeast of her summer range in the direction of her previously established winter range. Due to the timing and distance of her movement, she was assumed to be migrating back to her winter range.

Spring 2010

A total of 13 individuals (43.3%) migrated a mean distance of 9.6 km (SE = 1.7, Range = 18.6; Appendix F) during spring 2010. Seventeen (56.7%) deer did not migrate during this period. Average date of migration was 27 March and ranged from 15 March to 13 April. There were no documented dispersals during this migratory period.

Fall 2010

A total of 11 individuals (37.9%) migrated a mean distance of 9.8 km (SE = 1.9, Range = 19.8; Appendix F) during fall 2010. Fourteen individuals (62.1%) did not migrate during this period. Average date of migration was 2 December and ranged from 9 October to 9 January. One deer that migrated during spring 2010 and remained on her 2010 summer range until at least until 31 January 2011 when telemetry monitoring ended. This deer did not make a movement consistent with the definition of migration; instead made several short distance movements over the course of several weeks. However, the boundaries of her 2009-2010 winter range and 2010 summer range were less than 1.7 km apart so it is possible that this behavior was normal for this individual.

Migration Summary

Overall (2009-2010) mean migration distance (10.6 km, SE = 1.1, n = 38; Table 5) of all deer was similar ($F_{1,35}$ = 0.87, P = 0.357) between years and seasons ($F_{3,33}$ = 0.48, P = 0.7). In 2009, 11 (47.8%) of 23 radiocollared deer that lived through the spring migratory season demonstrated migratory behavior. In 2010, 9 (47.4%) of 19 newly collared deer exhibited migratory tendencies. During the course of the study, a total of 2 (10%) deer crossed management unit boundaries. It should be noted that even though these deer crossed management unit boundaries, their summer home ranges were within 1.6 km of or encompassed the county line.

Deer Winter Severity Index

Deer winter severity indices for winter 2008-2009 and 2009-2010 (Figure 3) were 47 and 91 respectively with values ≥100 being considered severe (Verme 1968). Seasonal migration was compared to snow depth (cm) and temperature (° C) during spring 2009, fall 2009, spring 2010, and fall 2010 (Figure 4, 5). Results indicated that onset of deer migration was related to temperature and snow depth, particularly during spring migration.

Home Ranges

A minimum of 25 and a mean 46.8 (SE = 0.04, n = 82) locations was used to calculate home ranges. Due to the timing of the capture during the winter of 2008-2009, an insufficient number of locations was collected to calculate home ranges. Issues with the tracking vehicle from 19 April to 19 May 2009 prevented the collection of locations during this time. Home ranges were similar between capture sites for all seasons.

During summer 2009 a total of 21 home ranges was calculated. Overall mean 50% core and 95% home range areas (Table 4) were 0.4 (SE = 0.05, n = 21) and 2.0 km^2 (SE = 0.2, n = 21), respectively

During winter 2009-2010 a total of 30 home ranges was calculated. Overall mean 50 and 95% home ranges (Table 4) were 0.5 (SE = 0.1, n = 30) 2.3 km^2 (SE = 0.3, n = 30), respectively

During summer 2010 a total of 31 home ranges was calculated. Overall mean 50 and 95% home ranges (Table 4) were 0.4 (SE = 0.1, n = 31) and 2.1 km^2 (SE = 0.3, n = 31), respectively.

Discussion

Seasonal Movement

Overall mean migration distance (10.6 km; Table 5) of female white-tailed deer in southeastern South Dakota was somewhat lower than previously documented movements in highly modified agricultural landscapes (23.2 km, Sparrowe and Springer 1970; 13.0 km, Nixon et al. 1991; 14.6 km, Kernohan 1994; 10.1 km, Brinkman et al. 2005; 10.1 km, Burris 2005; 14.6 km, Swanson 2005; 19.4 km, Grovenburg et al. 2009). Shorter migration distances for deer in this study could be due to a relatively higher human population density. Many radiocollared deer spent significant time bedded in shelterbelts associated with building sites. Deer were able to find suitable habitat without moving great distances because of the relatively large number of houses that exist across the countryside in Bon Homme County. Because deer were not monitored daily during migrations, total time en route was not known. Time spent in transit varied but was typically <1 week. This rapid movement was similar to what has been documented in previous studies in the region (Brinkman et al. 2005, Burris 2005, Swanson 2005, Grovenburg et al. 2009).

Migration strategies of white-tailed deer in the Midwest have been well documented (Rongstad and Tester 1969, Sparrowe and Springer 1970, Drolet 1976, Nelson 1995, VerCauteren and Hygnstrom 1998, Burris 2005, Swanson 2005, Grovenburg et al. 2011*a*). Of 28 radiocollared deer followed for ≥2 migratory seasons, 7 (25%) were obligate migrators, 5 (17.9%) were conditional migrators, and 16 (57%) were residents. Four of the 5 deer classified as conditional migrators made multiple trips to a seasonal range during a migration season but migrated during every season they were telemetered. The remaining conditional migrant failed to migrate during the last season she was monitored.

Several factors may play a part in initiating migration but snow depth and temperature have been demonstrated to be the primary stimuli (Verme 1968, Ozoga and Gysel 1972, Verme 1973, Drolet 1976, Blouch 1984, Tierson et al. 1985, Nelson 1995, 1998, Sabine et al. 2002, Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). In an attempt to correlate snow depth and temperature to migration timing, DelGiudice et al. (2002) created a white-tailed deer specific Deer Winter Severity Index. Average DWSI's for southeastern South Dakota during winters 2008-2009 and 2009-2010 (Figure 3) were 47 and 91. The winter of 2008-2009 was similar to the winters reported recently in other regions of South Dakota (Burris 2005, Grovenburg et al. 2009); however, the winter of 2009-2010 was colder than average and approached levels generally considered severe (Verme 1968). Based on the differences in the severity of the two winters, I expected the percentage of conditional migrators, or migrators in general, to increase during the more severe season (Nelson 1995, Sabine et al. 2002, Fieburg et al. 2008). The similarity in migratory behavior among years with different DWSI's in this study may suggest that conditional migration is of minor importance in this region than in more northern reaches of the white-tailed deer's distribution. However, due to the relatively short period that radiocollared deer were monitored, caution should be taken when assigning migration strategies (Fieberg et al. 2008)

Temperature was the most influential variable examined during this study with regard to migration timing. Snow depths possibly played a role in migration but by the time snow depths described as critical for white-tailed deer (30.4 cm, Drolet 1976, 35-40 cm, Nelson and Mech 1981, 40 cm, Sabine et al. 2002) had been reached, the majority of radiocollared deer had completed their migrations. In fall 2009, 75% of migrating deer moved during the period 27 November to 8 December. Temperatures during this period approached 0° C for the first time that winter and on 10 December reached a daily mean of −18° C, the lowest recorded to that point during fall 2009. During fall 2010, 83% of migrating deer moved between 7 November and 21 December. Again, this was the first time the mean daily temperature dropped below 0° C for the winter. There was a 20 cm snowfall during 11-12 December that coincided with the migration of 3 individuals. Migrations typically occurred when mean daily temperatures dropped below 0° C. Fall migration seasons were completed by the time temperatures remained below these levels for several days and snow depths reached critical levels.

The regular firearms season likely played little or no role in influencing fall migration. Mean migration date for fall 2009 (23 November, $n = 4$) was skewed due to an early migration on 11 October. The 3 remaining deer for that season all migrated between 27 November and 8 December, more than a week after the opening of rifle season. In 2010, the mean migration date (2 Dec, $n = 11$) was 2 weeks after the onset of the firearms season. While it is unlikely that the opening of the firearms season was responsible for a large portion of migrations, it could have resulted in a small number of deer initiating migration.

Spring migration was influenced by decreasing snow depth and increasing temperature. In 2009, 5 deer migrated during 15-25 March when average daily temperatures reached 13° C. Temperatures dropped following this period and migrations did not resume until 11 April when temperatures were again well above 0° C. Migration in 2010 did not begin until snow depth reached 0 cm and temperatures were above 0° C. Like 2009, migrations continued as long as mean daily temperatures were above 0° C. There may be other factors that play a role in migration. During spring 2009, daily mean temperatures exceeded 0° C for 4 days in late March but no radiocollared deer migrated.

Whether or not other deer migrated during this time is unknown but it may support the claim that factors such as photoperiod or vegetation status play a role in migration timing in addition to snow depth and temperature (Nixon et al. 1991).

Capture site 1 contained the upper reaches of Lake Lewis and Clark, a shallow-water section of the Missouri River that is several kilometers across and contains many braided river channels. Local residents observed deer occupying the cattail islands in the river bed from spring through fall. White-tailed deer are capable swimmers but will avoid swimming if possible (Michael 1965). It was hypothesized that because of the distance across the river, it would serve as a barrier to migration. Beginning in April in 2009 and 2010, deer began moving onto the cattail islands and were routinely located on the islands for several weeks at a time. While many deer utilized the dry islands during spring and summer, no migratory deer made a movement, initial or otherwise, onto or across the river channel. Though resident deer utilized the islands during summer months, no resident radio-collared deer were ever located across the river.

Home Ranges

The home range of a white-tailed deer must encompass enough resources to ensure the survival of the individual. In highly fragmented habitats, this may require home ranges that not only are quite large but also that shift between seasons and years (Marchington and Hirth 1984). In northern portions of white-tailed deer range, home range size also is affected by snow depth, temperature, and population density (Severinghaus and Cheatum 1956, Verme 1968, Nelson 1995, 1998, Sabine et al. 2002, Brinkman 2003, Burris 2005, Grovenburg 2007). Additional factors such as crop harvest, hunting pressure, geographic features and habitat characteristics also influence seasonal home ranges (Michael 1965, Sanderson 1966, Sparrowe and Springer 1970, Root et al. 1988, VerCauteren and Hygnstrom 1998). In agricultural areas, resources such as food (i.e. corn) and cover are unlimited for much of the summer season. Permanent cover is limited in this region, which causes white-tailed deer to select patches of habitat that contain both suitable food and cover during winter months.

In an attempt to conserve energy during winter months, deer will utilize the best available thermal cover in close proximity to a quality food source (Moen 1976, Parker et al. 1984). Because of this behavior, it is generally predicted that winter ranges will be smaller than summer ranges (Nelson and Mech 1981, Tierson et al. 1985, Mooty et al. 1987). This, however, has not been the case in highly fragmented habitats. Brinkman et al. (2005) had winter home ranges more than twice as large as summer home ranges. Likewise, Swanson (2005) and Burris (2005) also documented winter ranges that were larger than summer ranges in southwest Minnesota and eastern South Dakota. During this study, I estimated the mean summer home range to be only slightly smaller than the mean winter home range size. During the winter, white-tailed deer utilized hilly terrain too steep for row-crop agriculture as bedding sites. Deer would then cross open fields of harvested corn and soybeans to feed on silage and spilled grain in surrounding farmyards. This movement could encompass straight line distances of ≥1 km and is likely the reason for the larger winter ranges.

Management Implications

The current licensing system in South Dakota requires all interested parties to apply for a permit to deer hunt. These licenses are distributed based on deer population estimates in each county. While the regular rifle season occurs just prior to or during migration, the current hunting regulations allow for the harvest of antlerless deer during January, after the majority of the fall migration has occurred. Unseasonal weather events may cause deer to move earlier, concentrating them on winter ranges, which would leave much of the permit area void of deer and most of the deer population inaccessible to most hunters. Because of the demonstrated tendency for deer to move large distances, localized harvests in January after deer have migrated from their summer ranges have the potential to affect large areas surrounding the winter range.

Another concern for managers is the vegetative condition of the winter area. Most of the winter area was dominated by eastern red cedar, which provides excellent cover for deer both as a windbreak and a means to reduce snow depth. As cedars mature, they reduce the amount of grass available for cattle, which private landowners use to graze livestock on winter ranges during summer months. To maximize grass production, private landowners reduce or eliminate the number of mature cedar trees, creating a potentially serious condition for wintering deer. Identification of sensitive winter areas and subsequent regulation of those areas may be required if habitat degradation becomes an issue.

This study was designed to document seasonal movement in relation to management unit boundaries in southeastern South Dakota. Using results of this study, managers will be able to more effectively manage deer populations in this region. Due to the relatively short nature of this study, managers need to be aware that additional stochastic factors not documented in this study may play a role in seasonal management of white-tailed deer. Additional monitoring of local deer populations in the region with respect to winter weather, disease, and human factors is necessary to ensure proper management of the resource.

CHAPTER 3

SURVIVAL OF ADULT FEMALE WHITE-TAILED DEER IN SOUTHEASTERN SOUTH DAKOTA

Introduction

To prevent a recurrence of the over-harvest of deer populations of the late 1800s (Cook 1945), game managers need to closely monitor human influences on ungulate populations. Humans have been shown to be the primary factor in adult female mortality in highly modified agricultural habitats across the upper Midwest predominantly due to hunter harvest as well as vehicle collisions and poaching (Dusek et al. 1992, Nixon et al. 2001, Brinkman et al. 2004, Burris 2005, Grovenburg et al. 2011*b*). In addition to human-related mortality, white-tailed deer must overcome starvation, disease, and avoid a variety of predators such as wolves (*Canis lupus*) and coyotes (*C. latrans*; Mech 1984, Messier et al. 1986, Van Deelen et al 1997, Deperno et al. 2000, DelGiudice et al. 2002). Thus, knowing the cause-specific mortality for a given population is critical to successful management.

Survival estimates, like other population parameters, can be difficult and costly to collect causing managers to make educated guesses relative to population management. Because mortality rates have been shown to vary greatly depending on season, habitat, age, sex, and density (Dusek et al. 1992, Whitlaw et al. 1998, DePerno et al. 2000, DelGiudice et al. 2002), it is difficult to determine which survival estimates best predict the true rates of a given population. Natural mortality rates are typically low when compared to harvest mortality (Van Deelen et al. 1997, Brinkman et al. 2004, Burris 2005) but because natural mortality is often difficult to document (Dusek et al. 1992), it can lead managers to underestimate mortality creating a situation where overharvest is possible (Hoskinson and Mech 1976, Nelson and Mech 1986*a*).

Vehicle collisions are a growing concern for both humans and wildlife. As human populations increase and continue to encroach on wildlife habitat, interactions with wildlife will become a greater concern for wildlife managers. Even in heavily exploited populations, vehicle collisions continue to be a proximate factor in annual white-tailed deer mortality (Hubbard et al. 2000, Sudharsan et al. 2009). Factors such as human population, vehicle speed, traffic rate, surrounding habitat, and deer density have been used to categorize which sections of roadway are most dangerous for deer and commuters (Bashore et al. 1985, Hubbard et al. 2000, Farrell and Tappe 2007). Deer-vehicle collisions will continue to be a source of concern not only for deer population management but also in terms of human safety.

Mortality rates have been documented in a variety of habitats across much of the northern range of white-tailed deer (Nelson and Mech 1986*a*, Dusek et al. 1992, Van Deelen et al. 1997, Whitlaw et al. 1998, DePerno et al. 2000, Nixon et al. 2001, Delgiudice et al. 2002); however, minimal survival data exists for southeastern South Dakota. Therefore, the objectives of this study were to document overall, annual and seasonal survival, and cause-specific mortality of adult female white-tailed deer in southeastern South Dakota.

Methods

Female white-tailed deer were captured using a shoulder-fired net gun fired from a helicopter (Jacques et al. 2009, Helicopter Capture Service; Quicksilver Air, Fairbanks, AK). Upon capture, an aircrew member would exit the aircraft and hobble and blindfold the deer. The deer were then placed in a load bag and slung below the helicopter to a processing site. Once at the processing site, rectal temperature was monitored continuously until the deer was released. When conditions warranted (rectal temperatures at or above 40° C), a solution of ice water and isopropyl alcohol was immediately applied ventrally in an effort to limit the maximum body temperature of the deer. Deer were aged using tooth wear and replacement (Severinghaus, 1949) as yearling (1.5 yrs) or adult (>1.5 yrs.). Chest and neck girth measurements were used to estimate weight (Weckerly et al., 1987) and a colored, numbered eartag was affixed to each ear. An intramuscular injection of a broad-spectrum antibiotic was administered and each deer was fitted with a radiocollar (Advanced Telemetry System, Isanti, MN, USA) equipped with a mortality sensor designed to increase pulse frequency from 60 beats per minute (bpm) to 120 bpm if the collar remained motionless for >8 hours. After processing, the hobbles and blindfold were removed and the deer was released. Total handling time was monitored from the time the deer reached the processing site until the time the deer exited the processing area. All methods pertaining to capture of deer were approved by the Institutional Animal Care and Use Committee (IACUC, Approval No. 08-A028) at South Dakota State University and followed guidelines approved by the American Society of Mammalogists (Sikes et al. 2011).

Individual deer were monitored for mortality 2-3 times per week using a truck-mounted, null-peak antenna system (Brinkman et al. 2002) or an omni-directional whip antenna. Cause of mortality was determined using a combination of field necropsy and evidence at the site. If cause of death could not be determined in the field, deer were transported to South Dakota State University Animal Disease Research Diagnostic Laboratory for further investigation. Mortalities that occurred <26 days post capture were assumed to be capture related (Beringer et al. 1996) and were censored from the study. When possible, the front incisors were obtained for age analysis using cementum annuli to document the accuracy of age estimation by tooth wear used during capture.

Mortality data was recorded on a per-week basis. Survival rates were estimated using the Kaplan-Meier method (Kaplan and Meyer 1958) adapted for staggered entry (Pollock et al. 1989) using Program MARK version 4.3 (White and Burnam 1999). Seasonal survival was separated into three seasons, which were established to reflect the effects of hunting: Pre-Hunt (1 May-11 September 2009, 1 May-10 September 2010), Hunt (12 September-31 January 2009, 11 September-31 January 2010), and Post-Hunt (1 February-30 April 2009 and 2010).

Results

Forty-four adult female deer were captured and radiocollared during February 2009 (n = 25; Table 2, Appendix A) and January 2010 (n = 19; Table 3, Appendix B) at two capture sites in Bon Homme county in southeastern South Dakota. There were an additional two deer that were captured but were not radiocollared. The first was an adult doe that was net gunned in 2009. The capture personnel exited the aircraft but by the time the deer was reached, she had died. No necropsy was conducted to determine cause of death. The second female deer also was captured in 2009. After being processed, the deer was released and she attempted to reach security cover approximately 300 m away from the processing site. During the time the female was crossing an agricultural field, a landowner's dog began chasing the deer. The deer was unable to outrun the dog through deep snow drifts and due to capture myopathy was euthanized.

A total of 20 mortalities was documented during the 24-month study (February 2009-January 2011), and 19 were included in the survival analysis (Appendix C). Sixteen (84%) mortalities were attributed to human-related causes and one (4%) was due to natural causes. Hunting was the cause of 7 (36.8%) mortalities (Figure 3, Appendix C). Vehicle collisions also caused 7 (36.8%) mortalities; 2 (10.5%) mortalities were due to illegal harvest, 1 (5.3%) was attributed to natural causes, and 2 (10.5%) were the result of unknown causes. Fifteen (78.9%) deer died at capture site one and four (21.1%) died at capture site two.

A mortality signal was received from D113 on 12 January 2011 and the carcass was located the same day. There was some evidence of avian scavenging on one hindquarter but no other external injuries were observed. The deer was located wedged in the fork of two large oak (*Quercus* spp.) trees with front legs pinned along either side of the chest cavity. Due to the large amount of snow that had fallen over the previous three days, there was no other evidence related to the mortality at the site. Because the deer became lodged in the tree and likely died from exposure during the snow storm, cause of death was listed as natural.

There were two deaths that were attributed to unknown causes. On 8 September 2010, a mortality signal was received from D835. The deer was last located on 4 September 2010. The carcass was located approximately 300 m from the last known location, however, due to the relative inaccuracy of the prior location, the location of the carcass relative to the 4 September location may have been different. The collar was located with the intact spinal column and skull, however, there was no other evidence at the site to determine cause of death. Extensive scavenging had occurred, which scattered the remains of over an area approaching 200 m^2 possibly indicating that the carcass had been moved repeatedly over several days preventing the collar from activating the mortality mode. A mortality signal was received from D794 on 10 September 2010; the carcass was intact with no evidence of external injury. The carcass was taken to the SDSU Diagnostic Lab but the results of the examination were inconclusive. Due to the potential for bovine tuberculosis in the area, specific testing was done for this disease with negative results.

One deer was censored from the survival analysis. During capture 2009, an adult female had a release time of over seven minutes. Collar attachment and data collection commenced at a time similar to previously released deer, but the release time was increased due to the amount of time the deer struggled to remove the collar at the processing site. Technicians attempted to assist the deer by walking the deer towards escape cover and eventually the deer exited the processing site. D893 was found three days later in the bottom of a ravine approximately 1 km from the processing site.

Annual survival rates of radiocollared deer were 0.62 (SE = 0.1, n = 33; Table 6) in 2009 and 0.74 (SE = 0.1, n = 33; Table 6) in 2010. Overall (24 month) survival was 0.47 (SE = 0.1, n = 44). During 2009 seasonal survival during post-hunt, pre hunt, and hunt was 0.96 (SE = 0.04, n = 24), 0.91 (SE = 0.1, n = 23), and 0.63 (SE = 0.1, n = 21; Table 7) respectively. During 2010 seasonal survival during post-hunt, pre hunt, and hunt was 0.97 (SE = 0.03, n = 33), 0.91 (SE = 0.05, n = 32), 0.83 (SE = 0.07, n = 29; Table 7) respectively.

Discussion

Annual survival rates for white-tailed deer in southeastern South Dakota were similar to those reported previously for Illinois (56-92%; Nixon et al. 2001), New Brunswick (66-85%; Whitlaw et al 1998), northern New York (75-88%; Jones et al. 1997), northern Michigan (77%; VanDeelen et al. 1997), southwestern Minnesota (77%; Brinkman et al. 2004), northeastern Minnesota (79%; Nelson and Mech 1986*a*), central Black Hills of South Dakota (50-62%; DePerno et al. 2000), eastern South Dakota and western Minnesota (69-86%; Burris 2005), and east central South Dakota (65-84%; Grovenburg 2007, Grovenburg et al. 2011*b*).

Human induced factors such as hunting and vehicle collisions were the primary factors affecting survival of white-tailed deer in southeastern South Dakota. Hunting, including wounding loss, and vehicle collisions were equivalent as the leading cause of mortality during this study; each factor was responsible for 36.8% of mortalities documented during the study. This level of hunting mortality is below levels reported in eastern Montana (74%; Dusek et al. 1992), northern Wisconsin (63%; Lewis and Rongstad 1998), north-central Minnesota (43%; DelGuidice et al. 2002), southwestern Minnesota (43%; Brinkman et al. 2004), eastern South Dakota and southwestern Minnesota (68%; Burris 2005) and east central South Dakota (78%; Grovenburg 2007). While the “well-established road network” cited in previous studies (Brinkman et al. 2004) exists in southeastern South Dakota, during the hunting season deer were located along portions of the river where roadways were nearly nonexistent and hunting access was limited by private landownership.

Mean seasonal survival rates for post-hunt and pre-hunt periods were similar to those documented by Brinkman et al. (0.95 and 0.98, 1.00 and 1.00; 2004) in southwestern Minnesota, (0.97, 0.95; Burris 2005) in eastern South Dakota and southwestern Minnesota and in eastcentral South Dakota (1.00 and 0.97, 1.00 and 0.97; Grovenburg 2007). Seasonal survival rates during the 2009 hunting period were lower than those documented by Brinkman et al. (0.80; 2004), Burris (0.84; 2005), and Grovenburg (0.80; 2007). However, survival rates during the 2010 hunting season were similar to other studies. Seasonal survival was highest during pre- and post-hunt periods. This high summer survival was potentially attributable to abundant food (i.e., corn) and cover and minimal human activities (Nixon et al. 1991).

Vehicle collisions were a major source of mortality for white-tailed deer in this study. Seven vehicle mortalities were documented during the study. This is higher than previously reported in Illinois (17.7%; Nixon et al. 2001), Montana (4%; Dusek et al. 1992), east central South Dakota (11.1%; Grovenburg 2007), southwest Minneosta (21.4%; Brinkman et al. 2004), eastern South Dakota and southwest Minnesota (8.0%; Burris 2005), and Oklahoma (4.1%; Ditchkoff et al. 2001). Factors affecting the incidence of vehicle mortalities are beyond the scope of this study but it is important to note that factors such as traffic density, visibility, speed limit, and fencing can play important roles in collision rates in a given region (Bashore et al. 1985). These collisions can have repercussions related to the cost of the physical damages from the accident as well as the economic cost from loss of resources. These costs can be extensive with the social value of a single deer estimated at between $35-$1,468 (Livengood 1983, Romin and Bissonette 1996).

Management Implications

While hunter harvest in the region was found to be similar to previous studies in similar habitat, deer-vehicle collisions greatly exceeded previously described totals. This increase in vehicle collisions may have been due to many factors including human-based influences as well as natural influences such as topography. With the Missouri River forming a potentially impermeable barrier to the south, migrating deer may have been focused in a northerly direction, which concentrated deer travel across several east-west highways traversing the county. It is unlikely that game managers in South Dakota will be able to greatly influence vehicle travel in the region so they must account for increased vehicle-related mortality on adult deer in these types of situations. Increasing hunter harvest may reduce the number of vehicle collisions slightly but mortality factors in white-tailed deer have been shown to be additive at lower population levels (Dusek et al. 1992) so it is likely that large increases in hunter harvest levels will not affect the overall percentage of deer removed by vehicle collisions.

Winter weather during the study was milder than most other regions in South Dakota. While no adverse effect due to winter weather was documented during this study, a series of severe winters could reduce local deer populations. Adequate winter habitat is necessary for deer to survive these severe conditions so it is imperative that managers monitor winter ranges in the region and recognize habitat changes that could potentially reduce the ability of the habitat to provide winter cover.

CHAPTER 4

SIGHTABILITY OF WHITE-TAILED DEER IN SOUTHEASTERN SOUTH DAKOTA

Introduction

Success of a population management plan typically hinges on the ability of the managers to achieve population goals. Because of this, it is imperative that managers have a method that produces accurate population results on a consistent basis. Variables such as species, habitat, terrain, and funding all play a role in the method that will produce the best results for a given scenario. Aerial surveys with both fixed-wing and rotary-wing aircraft have been used by those looking to estimate population levels of a variety of animals (Otten et al. 1993, Choquenot 1995, Potvin et al. 2004). When using aerial surveys, it is virtually impossible to gain a complete count of all individuals in an area. Caughley (1974) reported failure rates that ranged from 12-71% attributed to visibility bias. This bias is a result of several factors inherent during aerial surveys and may include, among others, elevation and speed of the aircraft as well as strip width (Caughley 1974), habitat and topography, group size and activity of the animals (Samuel et al. 1987, Udevitz 2006), and observer experience and fatigue (Dirschl et al. 1981).

Ignoring the effects of visibility bias typically produces results that are negatively biased and as such, must be compensated. There are three general methods used to reduce visibility bias: refinements in survey methodology, the calculation of correction factors, and a combination of the first two methods (Otten et al. 1993). By modifying the census procedure, managers attempt to create a scenario where observers have the greatest chance of observing target individuals. Visual recapture of marked individuals (Rice and Harder 1977), stratified quadrat sampling (Beasom et al. 1986), and visual double-counts (Potvin and Breton 2005) are all examples of modified methodologies.

Correction factors are used to account for animals not seen on surveys. It should be noted that correction factors are not only species specific, but also habitat specific. Correction factors have been obtained by applying a partial regression to sightability factors (Caughley 1974) and comparing the counts from two independent observers (Cook and Jacobson 1979).

The South Dakota Department of Game, Fish and Parks use aerial surveys to estimate populations of antelope (*Antilocapra americana*), elk (*Cervus elaphus*), mule deer (*O. hemionus*) and white-tailed deer in the western portion of the state. However, due to habitat differences, the survey techniques used in the western half of the state are not applicable for surveys in the eastern half of the state. Populations of white-tailed deer have expanded rapidly in portions of eastern South Dakota while populations in other portions of the state are unchanged or declining. Because of this disparity, it is important that managers have an accurate tool to calculate populations across all counties in eastern South Dakota to ensure proper harvest rates. Thus, the objective for this study was to develop an aerial sightability model for use on white-tailed deer population surveys in southeastern South Dakota.

Methods

Female white-tailed deer were captured using a shoulder-fired net gun fired from a helicopter (Jacques et al. 2009, Helicopter Capture Service; Quicksilver Air, Fairbanks, AK). Upon capture, an aircrew member would exit the aircraft and hobble and blindfold deer. Deer were then placed in a load bag and slung below the helicopter to a processing site. Once at the processing site, rectal temperature was monitored continuously until deer were released. When conditions warranted (rectal temperatures at or above 40° C), a solution of ice water and isopropyl alcohol was immediately applied ventrally in an effort to limit the maximum body temperature of the deer. Deer were aged using tooth wear and replacement (Severinghaus 1949) as yearling (1.5 yrs) or adult (>1.5 yrs.). Chest and neck girth measurements were used to estimate weight (Weckerly et al. 1987) and a colored, numbered eartag was affixed to one ear while a small numbered, metal eartag was attached to the other ear. An intramuscular injection of a broad-spectrum antibiotic was administered and each deer was fitted with a radiocollar (Advanced Telemetry System, Isanti, MN, USA). In 2010, all new collars were white in color to increase the likelihood of identifying a radiocollared deer from the air. After processing, the hobbles and blindfold were removed and the deer was released. Total handling time was monitored from the time the deer reached the processing site until the time the deer exited the processing area. All methods pertaining to capture of deer were approved by the Institutional Animal Care and Use Committee (IACUC, Approval No. 08-A028) at South Dakota State University and followed guidelines approved by the American Society of Mammologists (Sikes et al. 2011).

The initial flights in 2009 were conducted in May in an attempt to take advantage of the color difference between bleached winter coats of white-tailed deer and greening landscape. Flights in 2010 were conducted with nearly 100% snow cover. Because sunlight was a variable that was being examined, sun direction was important, thus all flights were initiated 20 minutes after sunrise and commenced either when all deer were flown over or by noon, whichever was sooner. In 2010, flights were allowed to begin during late afternoon hours as long as there was sufficient time to attempt observations on all radio-collared deer before dark. Flights were conducted with four people in the airplane, a pilot, a nonobserver and two observers. One observer sat in the front right seat while the other observer occupied the rear left seat; the nonobserver monitored radio frequencies of deer.

Flights were flown in a Cessna 172 at a distance of approximately 61 m above ground level. Airspeed was maintained at roughly 161 km/hr. The pilot oriented the airplane on a heading of either north or south under the direction of the nonobserver to ensure radio-collared deer were on the flight path. The north or south heading was an attempt to eliminate sun glare or visibility bias. Observers were instructed to record all white-tailed deer observed within 400 m of the aircraft's groundtrack on their respective side of the aircraft. Data recorded included group size, activity level (i.e., moving, standing, bedded), if deer were in sunlight or shade, % canopy, % snow cover, and habitat. Habitat data was assigned to one of the following categories: trees, tall grass, short grass, standing corn, agricultural fields, and cattails. Once the aircraft had passed over all radiocollared deer in an area, the nonobserver notified the pilot that the ground track was suspended and determined which, if any, radiocollared deer had been seen. We considered a deer observed if the radiocollar deer was seen or if the group of deer containing the radiocollared deer was observed. We were able to determine that a radiocollared deer was present even if not seen by using the wing mounted antennas to pinpoint the location of the deer. If radiocollared deer were not seen, the airplane was flown repeatedly over the same ground track until all radiocollared deer were observed or it was determined that the deer were unobservable.

Data analysis was performed using SYSTAT 10.2 (SYSTAT 2002) using a stepwise regression. Observations (whether the deer was observed or unobserved) was the dependent variable. Independent variables were: group size, activity level, sun or shade, % canopy, % snow cover, and habitat. Variables that were significant ($P \geq 0.05$) were used to attempt to construct a model that could be used to predict the probability of sighting deer.

Results

A total of six sightability flights were flown in 2009 and 2010. In 2009, flights were conducted on 6 and 12 May. The 2010 flights were flown on 18, 25, and 26 February, and 5 March. During these flights, observations were attempted on 172 deer groups containing radio-collared deer, 44 in 2009 and 128 in 2010. Of the 44 attempted observations in 2009, 0 (0%) deer were seen on the first pass. In 2010, 9 of 128 (7.03%) were observed on the initial pass. For the duration of the study, a total of 19 observations were made utilizing as many passes as necessary to record an observation. Nine of the 19 observations were made on the initial pass while the remaining 10 observations required at least one additional pass before the collared deer was observed.

Group size of the deer observed on the initial pass ranged from 1 to 19 and averaged 6.8 (SE = 2.1, n = 9). All deer in the groups were moving at the time of observations. Three of these observations were made with canopy cover in the 0-25% range, four were in the 50-75% category and the remaining two were in canopy cover greater than 75%. Eight of the nine observations were made when the snow cover was ≥75% with the remaining observation occurring with snow cover in the 0-25% range.

Group size of deer that were not observed on the first pass but located on subsequent passes ranged from 1 to 25 and averaged 6.2 (SE = 2.2, *n* = 10). All groups of deer observed on the second or subsequent passes were moving at the time of observation. Seven of the ten of the subsequent observations were made in trees where the canopy cover was ≥50%. Remaining observations (*n* = 3) occurred in tall grass, short grass, and cattails. Nine of the 10 observations were made with snow cover ≥75% with the remaining observation occurring when there was no snow.

Based on these observations, the variables group size, behavior, habitat, observer, percent canopy, direction of travel, sun and percent snow cover were not significant at the $P = 0.05$ level (Table 7). Because of the limited number of instances where data were able to be recorded on observed or unobserved deer, I was unable to develop a reasonable sightability model for this study.

Discussion

There were several factors that created issues during this study, many of which were similar to results in other studies. The most problematic variable in this study was the habitat. The combination of steep terrain and a coniferous canopy presented a situation where less than 10% of radiocollared deer were observed on any one flight. Otten et al. (1993) found that canopy cover class was the only variable influencing sightability during helicopter surveys for elk in Michigan. According to Cogan and Diefenbach (1998), sightability varies inversely with increases in canopy cover for elk in Pennsylvania. Canopy cover has been shown to negatively affect sightability of elk in Idaho (Samuel et al. 1987), Dall's Sheep (*Ovis dalli*) in Alaska (Udevitz et al. 2006), and wild horses (*Equus calabus*) in the Australian Alps (Walter and Hone 2003). Due to the dense canopy in this study, deer were rarely spotted while bedded or motionless and deer that were observed were observed for minute periods of time as they moved through openings in the canopy. Similar results have been reported for moose (*Alces americana*) in Alaska (Gassaway et al. 1985) and bighorn sheep (*O. canadensis*; Bodie et al. 1995).However, canopy cover was not a significant influence on sightability for white-tailed deer in the Missouri River Breaks Region of central South Dakota (Grassel 2000).

Group size and behavior also seemed to have an effect on sightability during this study. Large groups of deer that fled from the airplane were easily spotted while smaller groups of deer that remained stationary were typically missed by observers. Group size is typically an influential factor in sightability of wild animals (Cook and Jacobson 1979, Samuel and Pollock 1981).

During the 2010 survey, nearly all flights were conducted with 100% snow cover. As a result, more deer, both radiocollared and non-radiocollared, were observed than flights conducted during 2009 with no snow cover. It should be noted, however, that due to the timing of the spring migration in both years the increase in deer sightings could also have been due to the higher density of deer on the winter range compared to the relatively low density of deer encountered during and after the spring migration. Snow cover has been cited as being highly influential in other survey studies. For example, Stoll et al. (1991) had a 99% detection rate in Ohio with uniform snow cover. Snow cover positively influenced the sightability of white-tailed deer in Missouri (Beringer et al. 1998). However, Grassel (2000) reported that snow cover had no influence on sightability of white-tailed or mule deer in the Missouri River Breaks Region of South Dakota.

Management Implications

The primary obstacle in this study was the vegetation encountered (eastern red cedar) on the winter ranges. Because these trees never lost their leaves, it becomes problematic to locate and identify deer within cedar thickets. Light snow cover during the second year of flights aided in observations but not to the point where influential parameters were identified. Because much of the winter habitat in the region is dominated by eastern red cedars, it may be beneficial for managers to explore other means to estimate population levels in the region.

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Table 1. Percentages of major land use for study sites in southeastern South Dakota.

	Agriculture	Pasture/Grassland	Developed	Forest	Open Water/Wetland
Yankton County	47.8	36.9	7.7	2.7	4.9
Bon Homme County	58.8	25.0	7.4	2.6	6.2

Table 2. Capture data by study site for radiocollared white-tailed deer southeastern South Dakota, February 2009.

	Site 1			Site 2			All Sites		
Age Adult (> 1.5 years) Yearling (1.5 years)	A	Y	Total	A	Y	Total	A	Y	Total
Number of Deer Captured	11	7	18	7	0	7	18	7	25
Mean (SE) handling time (minutes)	2.0 (0.003)	2.1 (0.01)	2.1 (0.004)	2.5 (0.04)	* 0	2.5 (0.04)	2.2 (0.01)	2.1 (0.01)	2.2 (0.01)
Mean (SE) chest circumference (cm)	105.5 (1.5)	100.0 (2.8)	103.6 (1.5)	104.5 (1.0)	* 0	104.5 (1.0)	105.3 (1.1)	100.0 (2.8)	103.8 (1.2)
Mean (SE) rectal temperature (°C)	40.0 (0.2)	40.0 (0.3)	40.0 (0.2)	40.3 (0.6)	* 0	40.3 (0.6)	40.1 (0.2)	40.0 (0.3)	40.1 (0.2)

* Indicates that no deer were caught in that category

Table 3. Capture data by study site for radiocollared white-tailed deer in southeastern South Dakota, January 2010.

	Site 1			Site 2			All Sites		
Age Adult (> 1.5 years) Yearling (1.5 years)	A	Y	Total	A	Y	Total	A	Y	Total
Number of Deer Captured	8	5	13	4	2	6	12	7	19
Mean (SE) handling time (minutes)	2.5 (0.02)	2.6 (0.01)	2.5 (0.01)	2.4 (0.02)	2.1 (0.01)	2.25 (0.02)	2.4 (0.01)	2.4 (0.01)	2.4 (0.01)
Mean (SE) chest circumference (cm)	103.7 (1.2)	101.6 (2.3)	102.9 (1.2)	105.4 (2.3)	97.8 (5.1)	102.9 (2.5)	104.2 (1.1)	100.5 (2.1)	102.9 (1.1)
Mean (SE) rectal temperature (°C)	39.9 (0.3)	40.2 (0.4)	40.0 (0.3)	37.8 (0.5)	38.6 (1.9)	38.0 (0.6)	39.2 (0.4)	39.7 (0.6)	39.4 (0.3)

Table 4. Mean seasonal 50% and 95% home ranges in km^2 for white-tailed deer in southeastern South Dakota, 2009-2010.

	50%	95%
Summer 2009 (*n*, SE)	0.4 (21, 0.04	2.0 (21, 0.2)
Winter 2009-2010 (*n*, SE)	0.5 (30, 0.1)	2.3 (30, 0.3)
Summer 2010 (*n*, SE)	0.4 (30, 0.1)	2.1 (30, 0.3)

Table 5. Mean seasonal migration distance pooled across all study sites in southeastern South Dakota, 2009-2010.

	All Deer
2009 Spring Migration (*n*, SE)	13.2 (9, 3.3)
2009 Fall Migration (*n*, SE)	12.2(4, 1.7)
2010 Spring Migration (*n*, SE)	8.5(14, 1.8)
2010 Fall Migration (*n*, SE)	9.8 (11, 1.9)
Pooled Migration (*n*, SE)	10.6 (38, 1.1)

Table 6. Annual survival rates of white-tailed deer in southeastern South Dakota, 2009 and 2010.

	2009	2010	Overall (24 month)
Number at -risk	24	33	44
Number of Deaths	10	9	19
Number Censored	0	0	0
Survival Rate	0.62	0.74	0.47
SE	0.09	0.07	0.08
CI lower	0.43	0.57	0.32
CI upper	0.78	0.86	0.63

Table 7. Seasonal survival rates for white-tailed deer in southeastern South Dakota, 2009 – 2010.

	2009			2010		
Season[a]	Post Hunt	Pre Hunt	Hunt	Post Hunt	Pre Hunt	Hunt
Number at-risk	24	23	21	33	32	29
Number of Deaths	2	2	7	1	3	5
Number Censored	0	0	0	0	0	0
Survival Rate	0.96	0.91	0.67	0.97	0.91	0.83
SE	0.04	0.06	0.1	0.03	0.05	0.07
CI lower	0.76	0.71	0.45	0.81	0.75	0.66
CI upper	0.99	0.98	0.83	0.997	0.97	0.93

[a]Seasonal intervals = Post hunt (1 February – 30 April), Pre hunt (1 May – 10 September) and Hunting (11 September – 31 January).

Table 8. Variables affecting sightability of radiocollared female white-tailed deer in southeastern South Dakota

Variable	χ^2	df
Group Size	0.841	1
Behavior	0.213	1
Observer	0.764	1
Habitat	0.199	5
Canopy	0.922	1
Sun	0.33	1
Direction	0.809	1
Snow	0.937	1

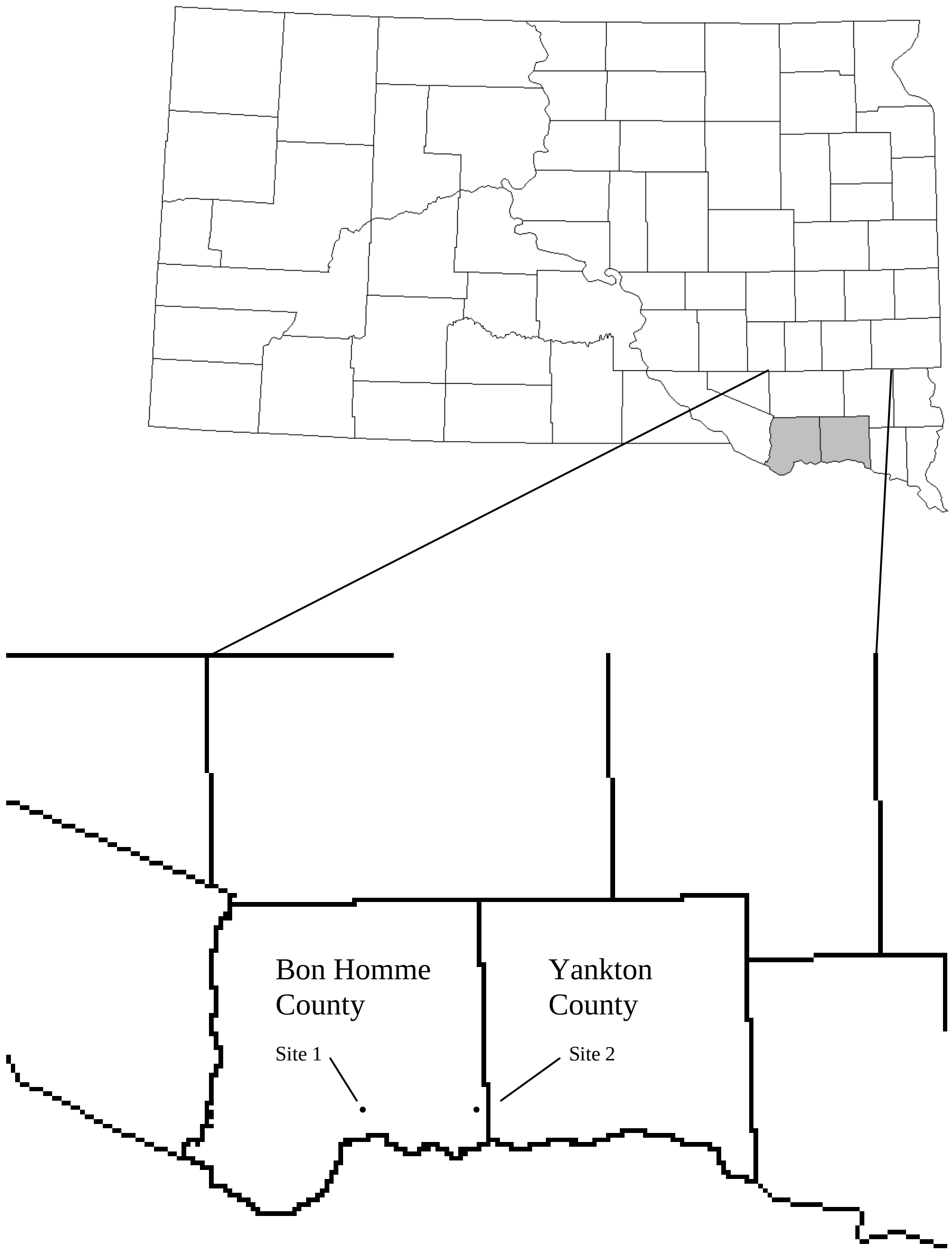

Figure 1. Study area and locations of two capture sites within study area for white-tailed deer in southeastern South Dakota, 2009-2011.

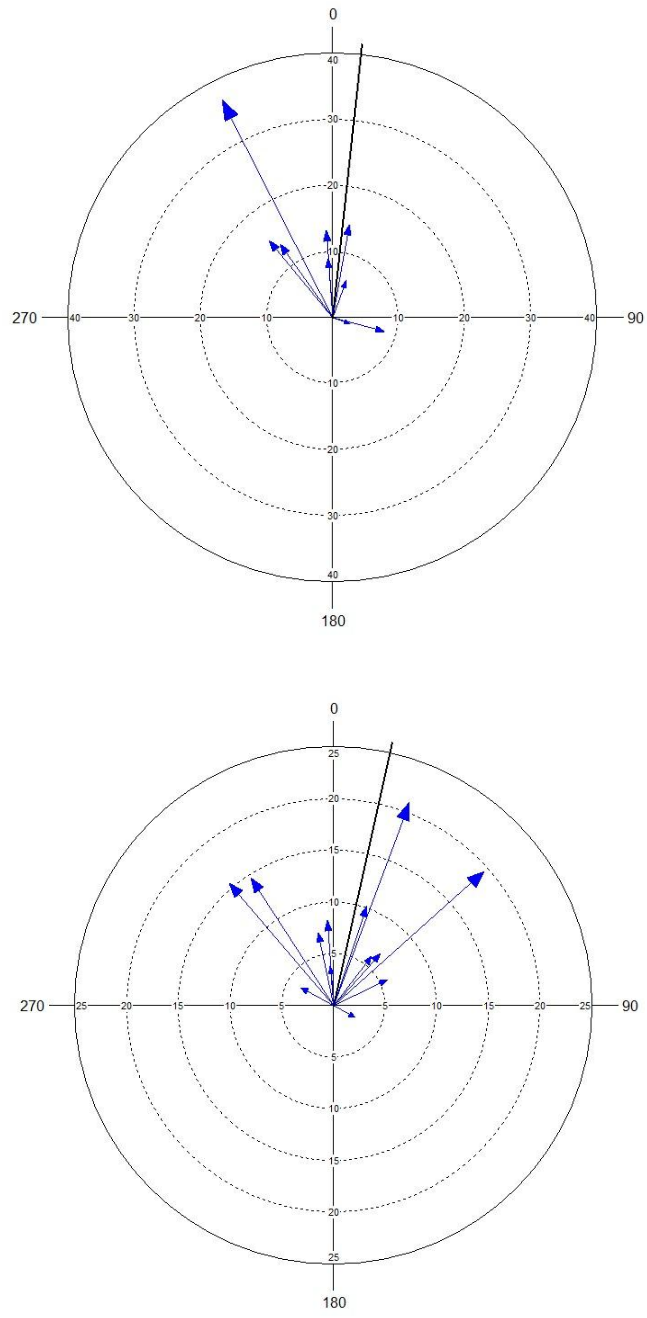

Figure 2. Spring 2009 (top) and Spring 2010 (Bottom) migration direction and distance for radiocollared white-tailed deer in southeastern South Dakota. Vectors show direction of migration (degrees), distance (km) migrated and mean direction migrated 12.6° (SE = 14.6°, n = 13), and 6.1° (SE = 18.9°, n = 9) respectively.

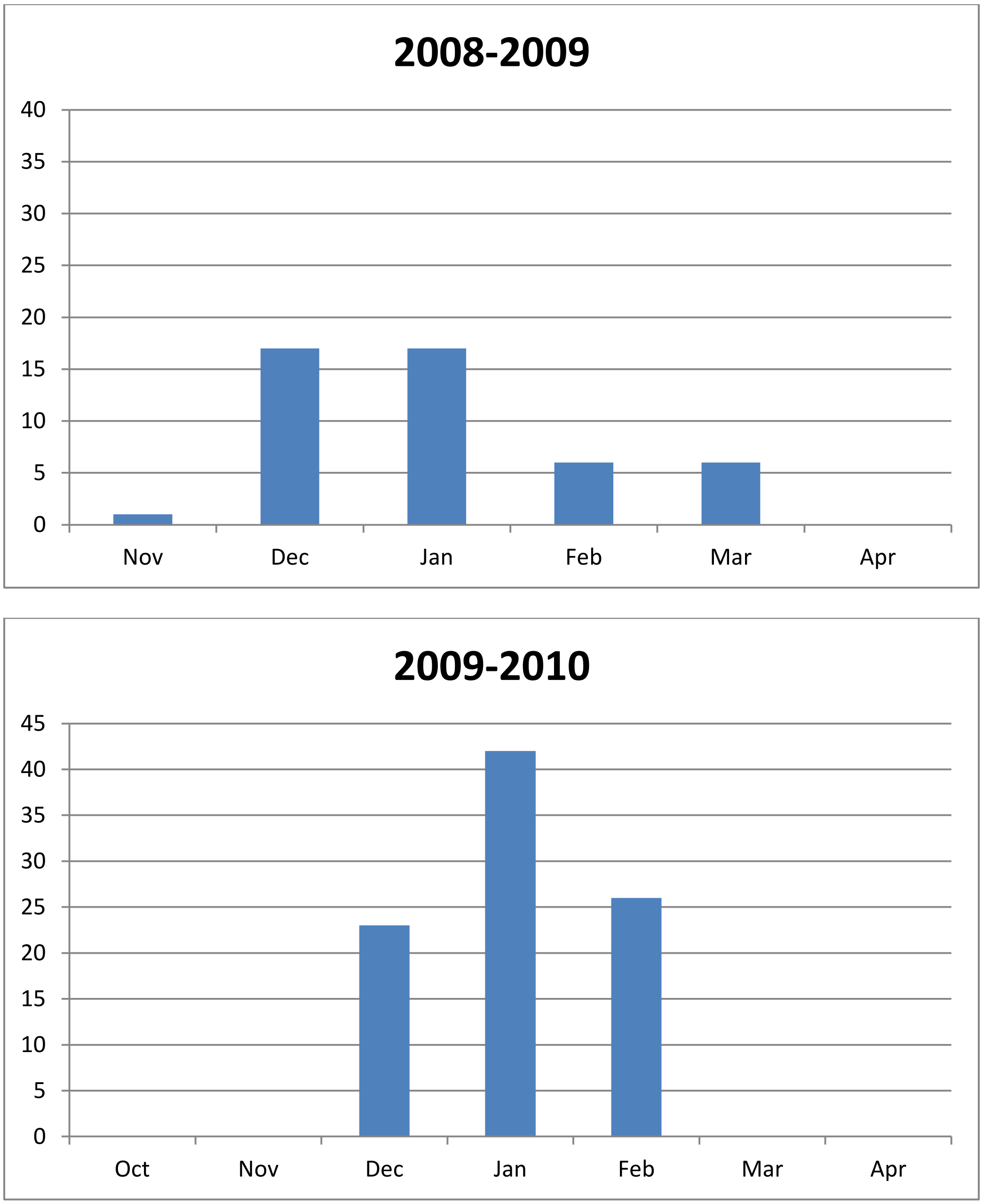

Figure 3. Monthly deer winter severity indices (DWSI) for study site in southeastern South Dakota. One point accumulated for each day ambient temperature was ≤-7 °C and an additional point accumulated for each day snow depth was ≥35 cm (National Climatic Data Center 2011, South Dakota Office of Climatology 2011).

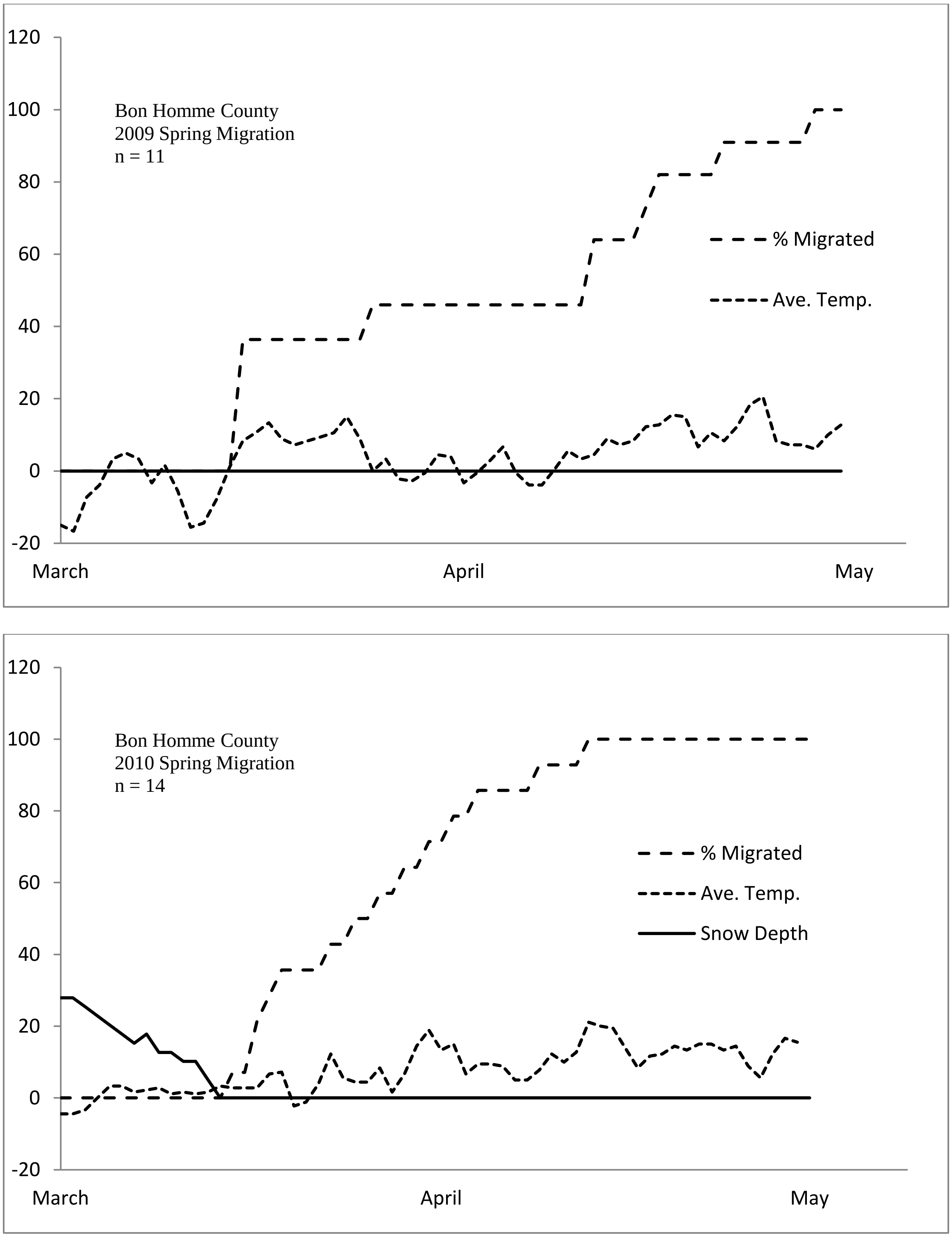

Figure 4. Spring 2009 (top) and Spring 2010 (bottom) migration for radiocollared white-tailed deer in southeastern South Dakota. The Y-axis is shared by the three variables snow depth (cm), temperature (°C) and % migrated.

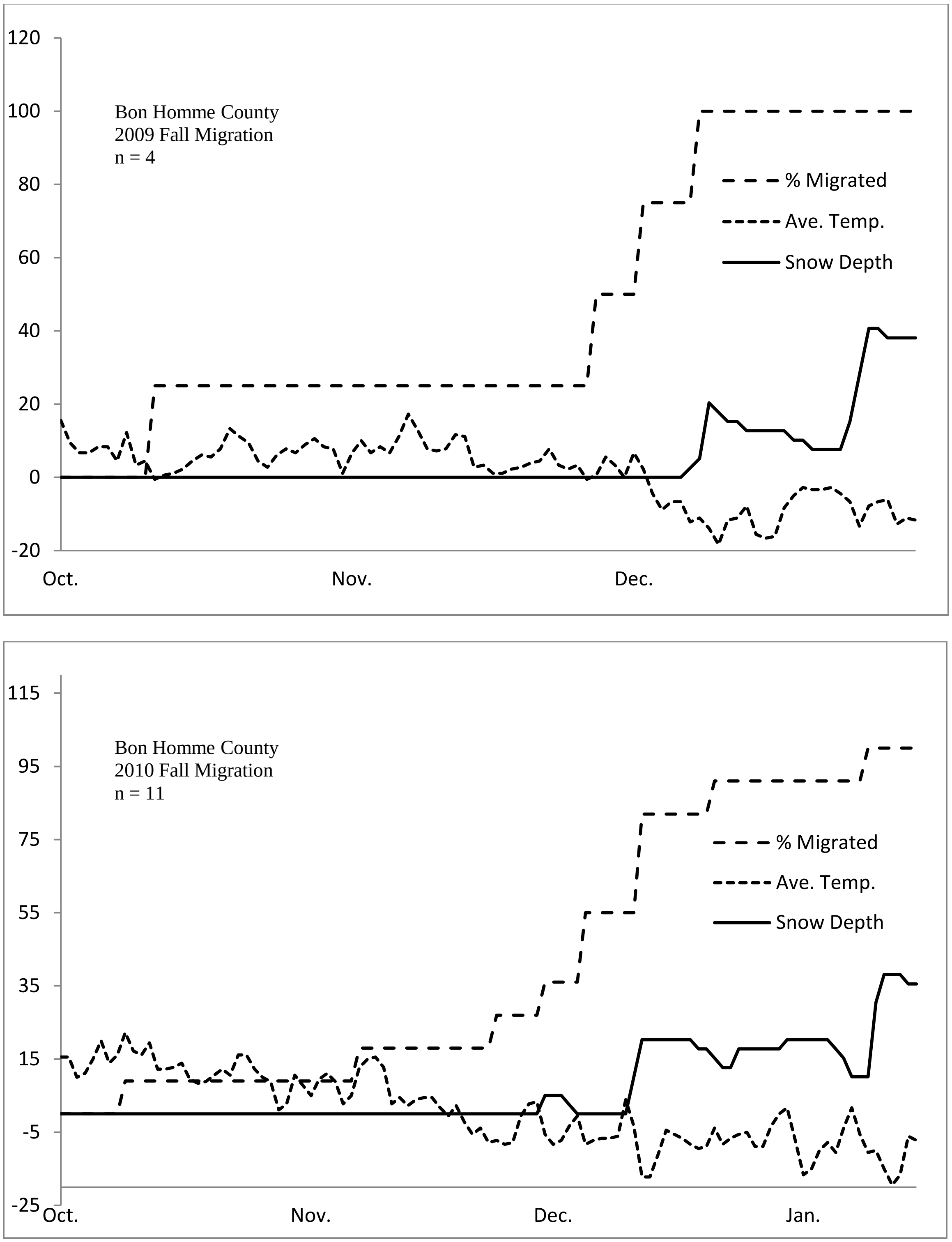

Figure 5. Fall 2009 (Top) and Fall 2010 (Bottom) migration for radiocollared white-tailed deer in southeastern South Dakota. The Y-axis is shared by the three variables snow depth (cm), temperature (°C) and % migrated.

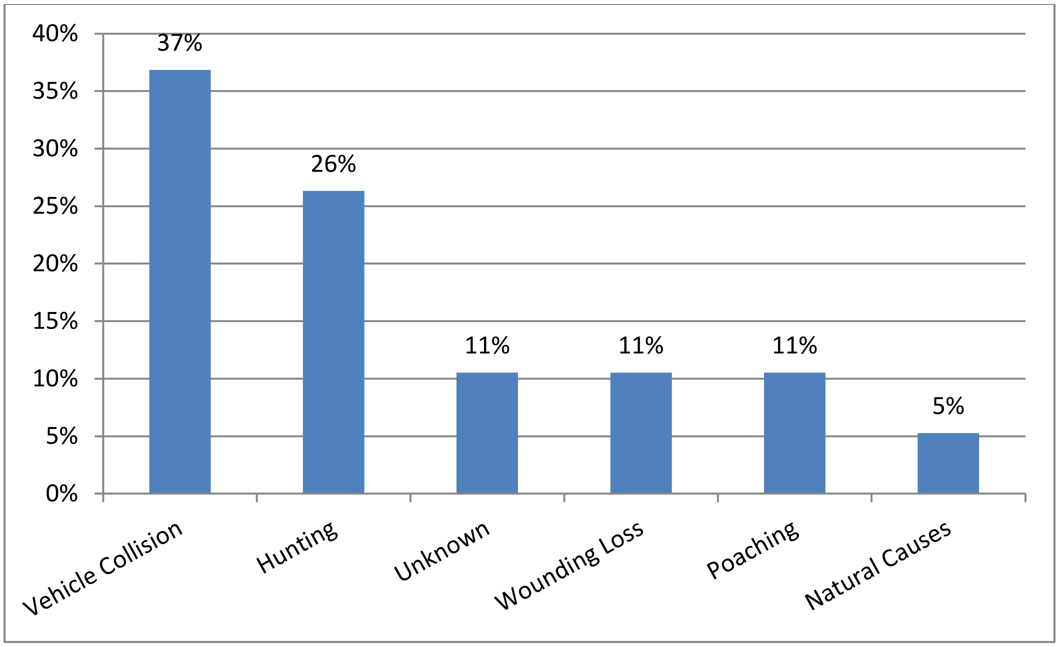

Figure 6. Cause-specific mortality (n = 19) of radiocollared white-tailed deer in southeastern South Dakota, 2009-2010.

Appendix A. Capture data for white-tailed deer in southeastern South Dakota, February 2009.

Capture Date	Study Site	Age at Capture (Yearling or Adult)	Collar Frequency	Processing Time	Chest Girth	Eartag Color and Number	Metal Eartag Number
2/17/2009	1	A	150.206	1:52	103	Orange 542	801
2/17/2009	1	A	150.092	2:18	102	Orange 550	802
2/17/2009	1	A	150.053	2:00	117	Orange 530	803
2/17/2009	1	Y	150.914	3:13		Orange 536	804
2/17/2009	1	Y	150.613	2:50	107	Orange 534	806
2/17/2009	1	A	150.954	1:50	106	Orange 539	809
2/17/2009	1	Y	150.805	1:53	102	Orange 537	814
2/17/2009	1	Y	150.474	1:45	89	Orange 540	821
2/17/2009	1	Y	150.455	2:08	101	Orange 532	815
2/17/2009	1	A	150.794	1:51	104	Orange 535	808
2/17/2009	1	A	150.975	2:00	105	Orange 143	820
2/17/2009	1	A	150.773	1:42	103	Orange 148	824
2/17/2009	1	A	150.935	2:36	101	Orange 538	867
2/17/2009	1	Y	150.685	1:43	95	Orange 533	823
2/17/2009	1	Y	150.131	2:01	106	Orange 531	812
2/17/2009	1	A	150.324	1:53	113	Orange 548	805
2/17/2009	1	A	150.011	2:07	104	Orange 549	817
2/17/2009	1	A	150.0333	2:00	103	Orange 528	811
2/17/2009	2	A	150.113	1:44	107	Black 473	822
2/17/2009	2	A	150.364	1:18	102	Black 470	813
2/17/2009	2	A	150.414	2:05	104	Black 397	810
2/17/2009	2	A	150.893	7:30	105	Black 474	866
2/17/2009	2	A	150.245	1:15		Black 467	865
2/17/2009	2	A	150.185	1:38		Red 511	868
2/17/2009	2	A	150.835	1:43		Red 522	863

Blank cells indicate no data

Appendix B. Capture data for white-tailed deer in southeastern South Dakota, January 2010.

Capture Date	Study Site	Age at Capture (Yearling or Adult)	Collar Frequency	Processing Time	Chest Girth	Eartag Color and Number
1/29/2010	1	Y	150.773b	3:18	94	Red 110
1/29/2010	1	A	150.206b	1:39	103	Red 114
1/29/2010	1	A	151.304	2:20	99	Red 113
1/29/2010	1	A	150.573	2:35	107	Red 112
1/29/2010	1	A	151.743	2:17	102	Red 111
1/29/2010	1	Y	151.335	1:38	108	Red 109
1/29/2010	1	A	151.565	1:48	110	Red 108
1/29/2010	1	Y	150.514	2:25	104	Red 105
1/29/2010	1	Y	150.724	3:30	102	Red 106
1/29/2010	1	Y	150.283	2:07	100	Red 104
1/29/2010	1	A	151.645	1:57	103	Red 103
1/29/2010	1	A	151.665	5:00	104	Red 102
1/29/2010	1	A	151.585	2:00	102	Red 101
1/29/2010	2	Y	150.324b	2:21	93	Red 119
1/29/2010	2	A	150.805b	1:43	102	Red 120
1/29/2010	2	A	10.914b	1:40	99	Red 118
1/29/2010	2	A	150.864	4:00	105	Red 117
1/29/2010	2	Y	150.455b	1:48	103	Red 116
1/29/2010	2	A	150.225b	2:03	103	Red 115

Appendix C. Home range size (km²) for white-tailed does by season in Bon Homme and Yankton counties 2009. Home ranges calculated using fixed kernel, LSCV method.

Frequency	Summer 2009 50% home range	Summer 2009 95% home range	Winter '09-'10 50% home range	Winter '09'-10 95% home range
150.011	0.36	1.36	0.68	3.05
150.033	0.52	2.19	0.39	2.24
150.053	0.17	1.00	0.80	2.97
150.092	0.20	0.85	0.13	0.66
150.113	0.07	0.34	0.26	1.14
150.131	0.89	3.83		
150.185	0.38	2.64	0.77	3.14
150.206	0.34	1.39		
150.206b			0.44	1.87
150.225			0.14	0.66
150.245	0.69	3.02	0.36	1.86
150.283			0.18	1.23
150.324	0.38	1.43		
150.324b			1.17	4.78
150.364	0.28	1.24	0.08	0.61
150.414	0.47	2.06	0.23	1.39
150.455	0.53	3.05		
150.455b			0.14	0.60
150.474				
150.514				
150.573			0.91	3.90
150.613				
150.685	0.29	1.19	1.19	5.57
150.724				
150.773	0.36	1.85		
150.773b			0.41	2.41
150.794	0.82	4.02	1.06	4.96
150.805				
150.805b			0.10	0.44
150.835	0.62	2.67	0.14	0.88
150.864			0.55	3.16
150.914	0.54	2.54		
150.914b			0.25	1.17
150.935	0.52	2.84		
150.954	0.02	0.13	0.20	0.93
150.975	0.62	2.87		
151.304			0.59	6.24
151.335			1.33	5.57
151.565			0.34	1.74
151.585			0.21	1.01
151.645			0.34	1.98
151.665			0.18	0.77
151.743			0.29	1.41

Blank cells indicate no data

Appendix D. Home range size (km²) for white-tailed does by season in Bon Homme and Yankton counties 2010. Home ranges calculated using fixed kernel, LSCV method.

Frequency	Summer 2010 50% home range	Summer 2010 95% home range
150.011	0.48	2.17
150.033	0.89	4.42
150.053	0.11	0.56
150.092	0.11	0.52
150.113	0.12	0.63
150.131		
150.185	0.27	1.28
150.206		
150.206b	0.54	3.22
150.225	0.22	1.11
150.245	0.70	2.82
150.283	0.77	3.95
150.324		
150.324b	0.21	0.94
150.364	0.09	0.47
150.414	0.33	1.35
150.455		
150.455b	0.23	1.01
150.474		
150.514	0.23	0.87
150.573	0.80	5.22
150.613		
150.685	0.32	1.42
150.724	0.71	3.25
150.773		
150.773b		
150.794	0.44	1.89
150.805		
150.805b	0.36	2.11
150.835	0.56	2.42
150.864	0.22	0.94
150.914		
150.914b	0.19	0.83
150.935		
150.954	0.08	0.58
150.975		
151.304	0.28	1.14
151.335	0.14	0.74
151.565	0.53	2.53
151.585	1.15	5.54
151.645	1.49	7.75
151.665		
151.743	0.26	0.94

Blank cells indicate no data

Appendix E. Mortality of radiocollared female white-tailed deer in southeastern South Dakota, 2009-2010.

Frequency	Capture location	Age at capture	Capture date	Cause of death	Date of death
150.893	Site 2	Adult	2/17/2009	Myopathy	3/1/2009
150.474	Site 1	Yearling	2/17/2009	Vehicle	4/14/2009
150.613	Site 1	Yearling	2/17/2009	Vehicle	6/2/2009
150.805	Site 1	Yearling	2/17/2009	Vehicle	7/13/2009
150.914	Site 1	Yearling	2/17/2009	Hunting	10/13/2009
150.773a	Site 1	Adult	2/17/2009	Wounding Loss	10/31/2009
150.455	Site 1	Yearling	2/17/2009	Vehicle	11/7/2009
150.206	Site 1	Adult	2/17/2009	Hunting	11/21/2009
150.131	Site 1	Yearling	2/17/2009	Hunting	11/24/2009
150.324	Site 1	Adult	2/17/2009	Vehicle	12/7/2009
150.935	Site 1	Adult	2/17/2009	Hunting	1/30/2010
150.975	Site 1	Adult	2/17/2009	Vehicle	2/16/2010
150.773b	Site 1	Yearling	1/29/2010	Vehicle	5/16/2010
150.835	Site 2	Adult	2/17/2009	Unknown	9/8/2010
150.794	Site 1	Adult	2/17/2009	Unknown	9/11/2010
150.514	Site 1	Yearling	1/29/2010	Hunting	11/25/2010
151.565	Site 1	Adult	1/29/2010	Wounding Loss	12/21/2010
150.364	Site 2	Adult	2/17/2009	Poaching	12/27/2010
150.324b	Site 2	Yearling	1/29/2010	Poaching	12/27/2010
150.113	Site 2	Adult	2/17/2009	Natural Causes	1/12/2011

Appendix F. Migration distance (km) for white-tailed does by season in southeastern South Dakota.

Frequency	Spring 2009	Fall 2009	Spring 2010	Fall 2010
150.011	0	0	0	0
150.033	0	0	0	0
150.053	0	2.18	2.32	2.48
150.092	0	0	0	0
150.113	0	0	0	0
150.131	8.11			
150.185	13.65	14.77	14.68	15.22
150.206	36.93			
150.206b			7.18	7
150.225			0	0
150.245	8.97	8.92	8.27	8.03
150.283			19.44	20.1
150.324	2.78			
150.324b			3.81	
150.364	0	0	0	0
150.414	15.16	15.28	15.49	15.7
150.455	0			
150.455b			0	0
150.474				
150.514			5.98	
150.573			0	0
150.613	0			
150.685	6.05	6.72	10.17	8.87
150.724			20.94	17.63
150.773	13.25			
150.773b			0	0
150.794	0	0	0	
150.805	0			
150.805b			0	0
150.835	0	0	0	0
150.864	0	0	0	0
150.914	14.31			
150.914b			0	0
150.935				
150.954	0	0	0	0
150.975				
151.304			0	0
151.335			5.78	2.37
151.565			0	0
151.585			0	0
151.645			6.79	
151.665			3.66	
151.743			0	0

Blank cells indicate no data
“0” indicates deer did not migrate